incorrect. In addition to mathematical problems and random notes on elementary mathematics through the calculus there are similar notes on astronomy and the calendar, and on mechanics and physics.

Louis C. Karpinski

SPECIAL ARTICLES

THE EFFECTS OF THYROID REMOVAL UPON THE DEVELOPMENT OF THE GONADS IN THE LARVÆ OF RANA PIPIENS

In a paper published in Science, November 24, 1916, a general account was given of my experiments performed in the spring of 1916 upon the removal of the anlagen of the anterior lobe of the hypophysis and of the thyroid gland in early tadpoles of *Rana pipiens*. It was shown that in each case this operation prevented metamorphosis. A full account of the results of the removal of the anterior lobe of the hypophysis has been published.[1]

Now the effect of thyroid removal upon the development of the gonads has been largely worked out. A full account of this latter phase of the work will be published in due time, together with papers by students of mine who have worked along correlated lines. It seems desirable in the meantime to give a brief account of the most interesting theoretical results of my investigations.

It was shown in my earlier paper that in the absence of the thyroid gland the tadpoles failed to undergo metamorphosis. Development went on normally up to the time when the hind limbs reached a length of 4–5 mm. At this stage the limbs entirely ceased to develop while the body as a whole failed to undergo further differentiation. While the tadpoles increased very greatly in size they at no time showed any further evidences of metamorphosis. This was true in spite of the fact that they eventually attained a length of body—exclusive of tail—varying from 30 to 43 mm. These figures are far in excess of any length normally attained by tadpoles of this species. From time to time specimens were killed and studied. At the date of writing, March 20, two of these tadpoles still remain alive and are in the same stage of bodily differentiation that they had reached the last of June.

This not only involves leg length, the failure of the tail to decrease in length and the failure of the mouth to change in form, but it involves the retention by the intestine of the original relative length characteristic of tadpoles. The lateral line organs became more highly developed than ever. In short a strictly larval form is maintained for months.

Now it is true that failure to metamorphose may likewise be attained by insufficient feeding if brought about at a sufficiently early stage of development. One larval tadpole with hind legs 5.5 mm. in length was kept in its larval condition by feeding very meagerly to November 15. At that time an effort was made to cause it to increase in size and to attain metamorphosis. Although it ate food it remained quite small, not showing any marked increase in size, nor did it show any strong tendency toward metamorphosis. When killed Febaruary 22 the testes were found to be quite small, they showed spermatogonia but no tendencies toward spermatogenesis. This was in strong contrast to the condition in a thyroidless tadpole with a body length of 43 mm. killed February 7. In this tadpole the testes were well developed, spermatogenesis was most active and thousands of completely formed spermatozoa were found in the testes, although the tadpole had remained in a strictly larval form with hind limbs only 5.5 mm. long and with a stomach and intestine length of 426 mm.—over 12 times the length of the corresponding organs in normal frogs at the time of metamorphosis.

The above cases are compared in order to show that although starvation may serve as one means of retarding metamorphosis, it also retards the development of the gonads and of the contained germ cells. This has been thoroughly established in an unpublished paper by Mr. Wilbur Swingle, one of my graduate students who carried out a series of experiments upon this same species. This case is cited to obviate the objection that the conditions here set forth might have been produced by starvation and not in thyroidless tadpoles

[1] *Biological Bulletin*, March, 1917.

properly fed. The continued development of their gonads and germ cells, and the normal metamorphosis of the similarly fed controls all show conclusively that we are here dealing with conditions resulting from the removal of the thyroid glands.

It must be kept in mind that the thyroid anlagen were removed at their very inception. It is fair to say that in these tadpoles there has never at any time been any thyroid secretion. A careful study of serial sections has demonstrated with certainty the total absence of these glands in the crucial cases used as a basis for this work.

The germ glands of the thyroidless tadpoles develop quite normally throughout, both as to structure and rate of development. When the operated tadpoles begin to lag behind the controls in general bodily differentiation, the gonads have already undergone sexual differentiation but have not yet shown any tendencies toward spermatogenesis. The remarkable feature of these experiments is seen in the fact that although differentiation of the soma halts completely at this early stage, the gonads continue to develop normally, keeping pace at every stage with the development of the gonads in control specimens. This applies both to the development of the gonads as a whole and to the development of sperm and ova.

At the time of metamorphosis the testes of both controls and thyroidless specimens showed similar dimensions. In no cases were there evidences of spermatogenesis. A thyroidless tadpole killed September 14 showed very active stages of spermatogenesis terminating in the production of many spermatids; but as yet no spermatozoa. Ripe spermatozoa were, however, found in a thyroidless tadpole killed December 15. In this case they were few in number, but in a thyroidless tadpole killed February 7, to which reference was made above, they were very numerous. This latter specimen had testes nearly twice as large as those of young frogs at the time of metamorphosis and of course very far beyond the condition found in tadpoles of a similar stage of body differentiation.

No less striking were the conditions in female specimens. At the time of metamorphosis, the central cavity of the ovary had formed, but the organ had not yet become folded as was later to be the case. All but a few scattered germ cells had become converted into large oocytes. An average of 12 of the largest measured showed dimensions of .2025 mm. $\times$ .2502 mm. As time passed, the thyroidless tadpoles showed continued growth of the ovaries. On February 14 they reached a size twice as great as at the time of metamorphosis. During all this time the oocytes of the thyroidless tadpoles steadily increased in size, as seen in specimens killed from time to time. In a thyroidless tadpole killed February 14 the average dimensions of the oocytes were .4027 mm. $\times$ .5207 mm. It is quite interesting to compare with this the conditions found in a normal young frog that metamorphosed last summer, living in the open and reaching a length of 48 mm. When it was killed March 13 the larger ova were seen to have reached an average size a trifle below that of the case just given, namely, .4123 mm. $\times$ .4540 mm., although the ovaries as a whole were somewhat larger, 8.05 mm. $\times$ 99.2 mm. as compared with 6.6 mm. $\times$ 7.2 mm. in the thyroidless tadpole killed March 15. This is probably due to the difference in bodily nutrition and is about proportional to the length of body of the two specimens compared.

From all this evidence I feel that we are justified in stating that the absence of the thyroid gland does not affect the development of the gonads or germ cells up to the time of sexual maturity in the male nor does it hinder the development of the ovary and ova, at least up to the period when the ova are visible with the naked eye. It is, of course, possible that the astonishing modifications of the soma may later secondarily affect the nutrition of the developing ova, but this is beyond the point.

These results are in line with some unpublished work by Mr. Wilbur W. Swingle, who at my suggestion studied the effects of thyroid feeding upon the germ glands and germ cells of *Rana pipiens* tadpoles. He shows that while this brought about the well-known

result of hastening metamorphosis with all of the attendant modifications, as had been known from the work of Gudernatsch, it did not in any wise modify the rate of development of the germ glands and germ cells.

The most striking result of all is the evidence brought forth to show that germ cells and soma are different in their nature, that the germ cells are unaffected by the thyroid, while the soma is so profoundly influenced by it. It is possible that further work may show that there are other structures that continue their development unhindered in the absence of the thyroid gland, but the work thus far has failed to demonstrate them.

This investigation throws light upon the problem of neoteny. We can with perfect justice say that we are here dealing with a case of artificially produced neoteny in a form which does not show it in nature. Here we can point to a very specific cause for this phenomenon, about which there has been so much conflicting speculation.

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THE STANSIPHON

Amongst the many interesting and useful pieces of apparatus shown in the scientific exhibit during the Christmas meetings of the American Association for the Advancement of Science was a self-starting siphon, the trade name for which is the Stansiphon.

For the information of those members of the society who did not see the model shown at that time and in the general interest of science, I am giving a brief description of its construction and operation followed by a statement of some of its more practical applications as well as inherent limitations as at present constructed.

The self-starting device is shown in Fig. 1 and consists of a bulb (4) sealed into the lower end of the tube (2) and an inner tube (5) sealed into the base of the bulb and reaching into the opening of the bulb at the top. Here the end is somewhat constricted and its size and position with respect to the top of the bulb is so adjusted that an "air trap" is produced at (6). A small opening (7) is made at the lower part of the bulb.

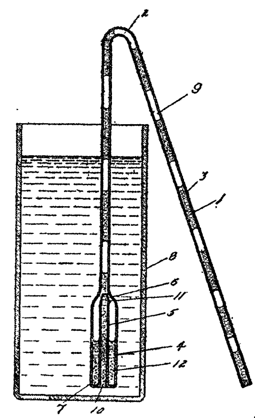

Fig. 1.

If the bulb be inserted to a considerable depth into the liquid to be siphoned, the liquid flows into the bulb through (7) and displaces the air which with the water passing through the inner tube (5) rises in a broken column in tube (2) and flows out through the delivery tube.

The height to which the given liquid may be raised will depend on the size of the bulb, the depth to which it is immersed, the construction of the "air trap," the material of which the siphon is made, the rate at which the bulb is inserted, etc. To operate successfully on ordinary liquids the Stansiphon should be immersed to a depth at least two or three times the length of the bulb.

Preliminary experiments were made by the inventor on water and the present design has greatly increased the efficiency of the siphon, both as to height lifted, and the rate of flow. A design of larger size has been made which successfully siphons acids from carboys, but owing to the heavy density of these acids it works relatively slowly as compared with water. Light oils such as kerosene and gasoline are readily siphoned by this method, but as yet a suitable design depending on this principle has not been found for the heavier oils.

The wide application of the Stansiphon is